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A model for exploring technological changes in new systems

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Abstract

This paper presents a product model for capturing the information of technological products and processes (TPP). It presents a generic model to discern the changes occurring in knowledge level of technological systems during design activities. The proposition is the Product Evolution Exploring Model (PEEM) that was initially developed within DEFI (Definition of inventive efficiency) project to support the measurement of novelty. PEEM helps to distinguish the functional, behavioral and structural changes in a common level of technical characteristics. The ultimate objective of PEEM is to provide a data base of applied knowledge in technological systems during design processes for supporting the framework of inventive design performance measurement system (IDPMS) within the DEFI project.

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Keywords: data representation; knowledge-based engineering; technological design; inventive design performance; TRIZ

1. Introduction

Distinction of new demands in design engineering creates new research orientations, which needs to be supported by developing new tools and adapting them. Product models is a key tool and has a large relationship with different research in technological design [9].

In general, the purpose of product models is to provide TPP [8] data concerning their objective, creation, erection, operation, structure, manufacturing or construction, usage, storage and recycling. In other words, the product models are intended to capture the information of different stages of TPP life cycles.

After extensive research in design and manufacturing engineering from 1984 to 2002, ISO 10303 is accepted as a standard for product data representation and exchange (STEP). Initial STEP applications were considered to use

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the outcomes of design activities after all decisions about geometric information [3] [4], and more recent STEP applications have been developed to support some types of non-geometric information [1].

In 1999 R. Brimble et al. [5] proposed the MOKA modeling language (MML) which considers all product lifecycle data based on five viewpoints: function, behavior, structure, technical solution, and representation [5].

In October 2002, despite the emergence of the system modeling language (SysML) in July 2002 to model the earlier stages of design processes, S. J. Fenves et al. proposed the core product model (CPM) to support the full range of product lifecycle management (PLM) [2]. They revised CPM in 2004 and 2008 [1]. Later M. Labrousse et al. 2008 [6], proposed FBS-PPRE model to improve and complete the PLM effectiveness.

Although MML, CPM and FBS-PPRE are dedicated to knowledge based engineering (KBE) and are used to extract and model the knowledge applied in technological systems, none of them was able to create a complete data list that can be used for detecting the inventive value of systems.

The product evolution exploring model (PEEM) is a new product model which has been developed to supply the related information for detecting the changes in a new system. It's a tool for supporting the framework of inventive design performance measurement system (IDPMS) in the DEFI (Definition of inventive efficiency) project.

Nowadays innovation management needs to enhance the inventive performance of a company; supplying the applicable data for product & process innovation during development processes becomes particularly important.

This work aims to present the PEEM as a common product model, at the first step of its development, to get the necessary data for detecting novelty. In the remainder of this paper the term of 'system' is used instead of TPP [8].

2. PEEM; A product model for exploring inventions

The product evolution exploring model (PEEM) is a generic model for acquisition of applied knowledge in technological systems with the aim of exploring the design changes during inventive design activities. PEEM is an abstract model that uses a generic semantic policy for gathering product information. The semantic policy of the PEEM generally is same with the older product model, and the difference appears when it borrows the TRIZ [10] terms and uses a Triz-based technical analysis viewpoint.

Fig. 1. Tumbler stainless steel cup as an example used for exploring PEEM.

PEEM explores the point of novelty in a new system by detecting the applied changes in knowledge level by comparison with the existing systems. Technological systems are the key objects of PEEM to be inspected from four viewpoints [Fig.2]:

- Environmental;
- Functional;
- Behavioral;
- Structural;

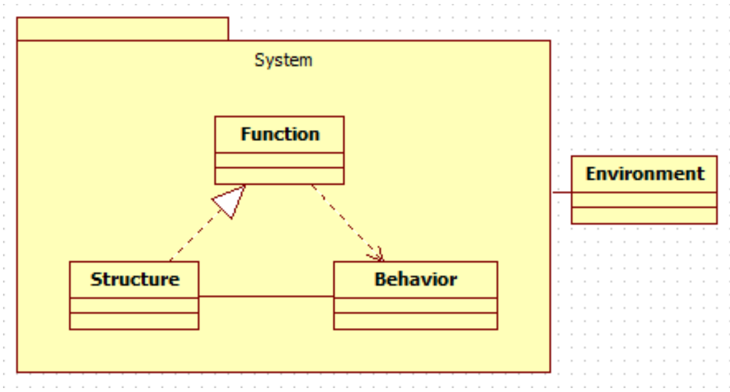

Fig. 2. Different aspect of the technological systems analysis in PEEM.

PEEM consists of eight abstract classes in the higher level of the data characterization for representing the objects and the properties of each exploration viewpoint. Figure 3. represents the abstract classes of the PEEM.

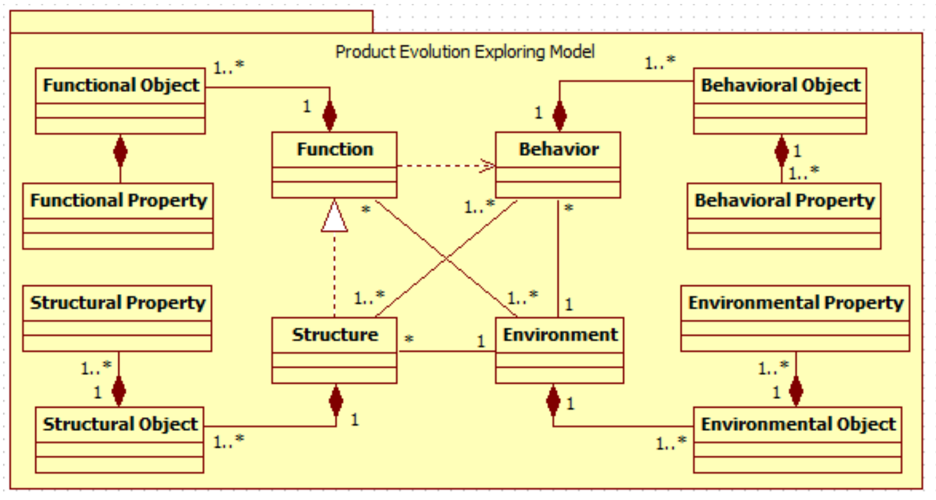

Fig. 3. Abstract classes in PEEM

In this work, the presentation of PEEM is done with considering the tumbler stainless steel cup [Fig. 1] as an exemple of the technological systems to be explored. This simple system helps to clarify the terms and the usage instruction of the PEEM.

2.1. Environmental viewpoint

Environmental aspects of a system refers to the specific condition that ensures the system operations. This operational condition is defined by the designers and constructors of systems [Fig. 4]. Environmental object classes in the PEEM are defined as:

- Useful Object: represents the objects that enters the system as raw materials and exit from the system as the useful output for consuming. E.g. the hot coffee in the tumbler cup.
  - Main Useful Object (MUO): represents a type of useful objects that are used by the main useful function of a system (MUF) (c.f.2.2.). E.g. the hot coffee in the tumbler cup.
- Actor: represents the environmental objects that provide systems for operation, and consume the useful objects.
  - Main Specific Consumers (MSC): represents the systems or the persons that/who are specifically defined to be served directly by the output objects of a system.
    E.g. the MSC of the tumbler cup is someone in a car such as driver.
  - Main Specific Operators (MSO): represents the systems or the persons that/who are specifically defined to provide directly a system to operate. E.g. anybody (human) as the MSO of the tumbler cup can provide the system to operate.
- Super-System Objects (SSO): this class represents the necessary objects in the operational condition of a system. They are defined for the system operation. This class object doesn't include the useful objects or the actors. E.g. the cup holder in a car is a defined SSO to hold the tumbler cup during operation.

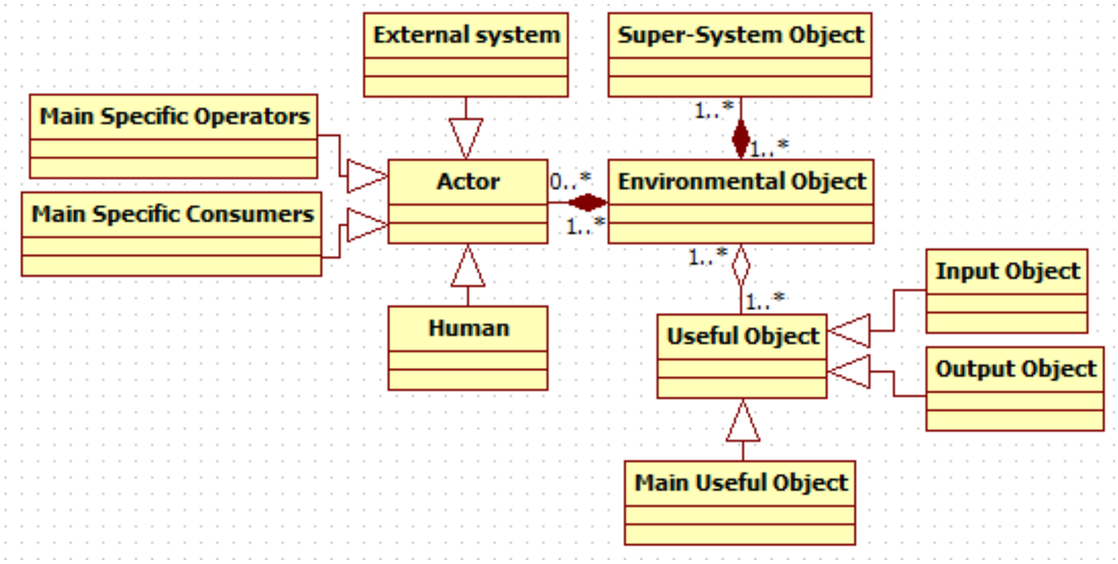

Fig. 4. Environmental object in PEEM

2.2. Functional viewpoint

Functional aspect of a system refer to the reason for which the system (or its subsystems) exist. The system function is what the system is supposed to do [2]. Indeed the function is the last behavior during one cycle of system operation (period) for supporting user requirements (desires). The functional objects of a system are classified in six categories:

- Main Useful Functions (MUF): represents the primary functions of a system. The primary functions are those functions that when eliminated would frustrate the other complementary functions of a system. MUF is the minimum function that is distinguished as the identity function of a system. E.g. containing the consumable liquids is the MUF of the tumbler cup.
- Main Complementary Functions (MCF): represents the complementary functions of MUF in a system. These functions interact directly with the MUO. E.g. maintaining the liquid temperature in the tumbler cup.
- Loading Complementary Functions (LCF): represents the defined functions for loading the input useful objects in a system. E.g. pouring consumable liquid in the tumbler cup.

- Discharge Complementary Functions (DCF): represents the defined functions for discharging the output objects from a system. E.g. evacuating consumable liquid from the tumbler cup.
- Super-System Complementary Functions (SCF): represents the related functions to the super-system objects. These functions don't have any interaction with MUO. E.g. holding the tumbler cup.
- Following Complementary Functions (FCF): represents the defined functions to indicate the system states. These functions monitor the system operation for the user [7].
  E.g. the water level gage on a tumbler cup.
- Controlling complementary Functions (CCF): represents the defined functions to command and control a system operation. This type includes those functions that control the system operations by a command signal [11]. E.g. pushing a button on an electrical tumbler cup for warming up the liquid.
- Discrete Supplementary Functions (DSF): represents those functions that don't have any interaction with MUO and the system operation. These functions have been embedded on a system to serve the user, consumer, operator and even those who have no relation with the system but are in the context of system operation. E.g. a digital watch on the exterior surface of a tumbler cup.
  Figure 5. presents the relationships of the function objects in the PEEM.

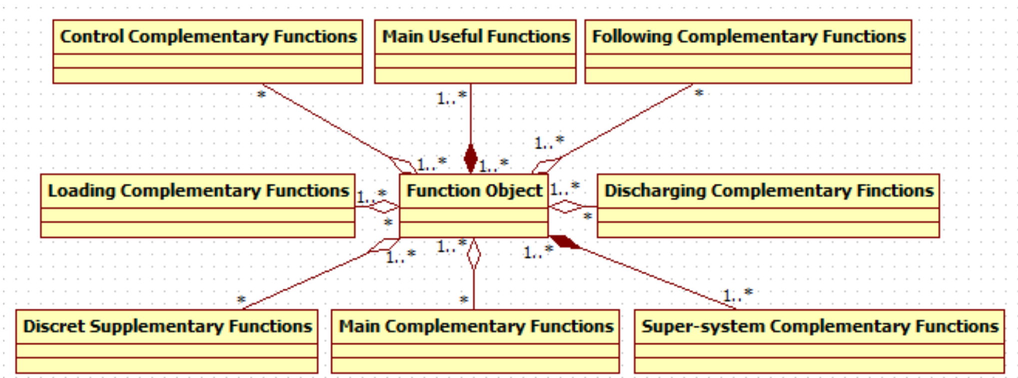

Fig. 5. Functional objects in PEEM

The functional properties are considered as [Fig. 6]:

- Action: is a definition of the functions by using a verb in infinitive form. E.g. <to contain> for presenting the MUF of the tumbler cup.
- Criterion: represents the related criteria of each action. E.g. the volume as the criterion of containing function.
- Unit: represents the unit of criteria. E.g. milliliter as the considered unit for the volume.
- Constraint value: represents the limit or constraint values of each criterion in a system. E.g. maximum and minimum volume for loading and discharging liquid in the tumbler cup.
- Useful Object: is one of the environmental objects that is considered as the property of actions with all its belonging objects; Main useful object, Input object, Output object.
  E.g. containing the hot coffee in the tumbler cup.

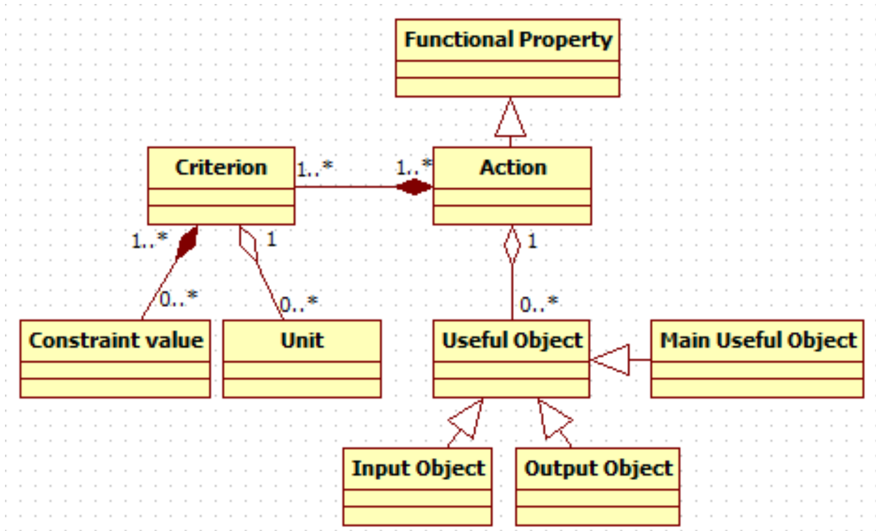

Fig. 6. Functional properties in PEEM

2.3. Behavioral viewpoint

Behavioral aspect of a system refers to the behavior of the system structure for supporting defined functions of the system. System behavior is run by flowing energy through the system structure. Conduction of energy along the structural entities of a system is characterized by the following object classes [Fig. 7]:

- Transition: represents energy transportation through entities. E.g. flow of thermal energy across the interior shell of the tumbler cup.
- Transmission: represents the importation and the exportation of energy in/from entities. E.g. the transfer of the liquid gravity force from the main shell to the plastic seating area of the tumbler cup.

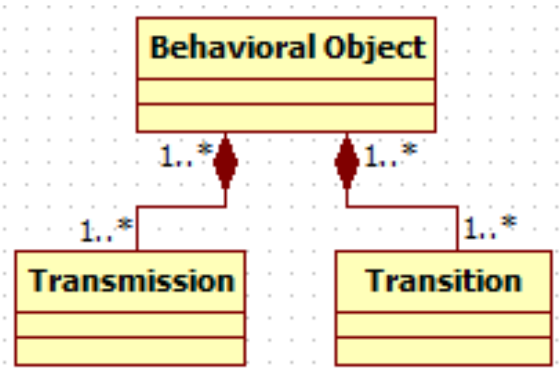

Fig. 7. Behavioral objects in PEEM

The behavioral objects are characterized by their properties [Fig. 8]:

- Scientific Phenomenon: represents the physical effects occurring during the system operations. E.g. the convection and the conduction of heat transfer.

- Energy: represents the energies that enter in each entity and exits from it.
  - Input energy: represents the input energy of an entity.
  - Output energy: represents the output energy of an entity.
- Source of energy: represent the sources of energy supplied for each scientific phenomenon. E.g. the heat of coffee is the source of energy at the first convection and conduction across the interior shell of the tumbler cup.
- Substance: represents the chemical form of each entity that contributes as a matter to the scientific phenomenon. E.g. the stainless steel (the cup shell) is the substance during the convection of heat transfer.
- Fundamental state of matter (FSM): represents the fundamental state of entities (solid, liquid, gas, and plasma) during the system operations. E.g. the FSM of the cup shell is solid during the operation.
- Position in CCS: represents the local position of each entity according to its initial position on the Cartesian Coordination System (CCS). E.g. moving the cup position for transferring its contents in the mouth of consumer. Figure 8. presents the behavioral properties.

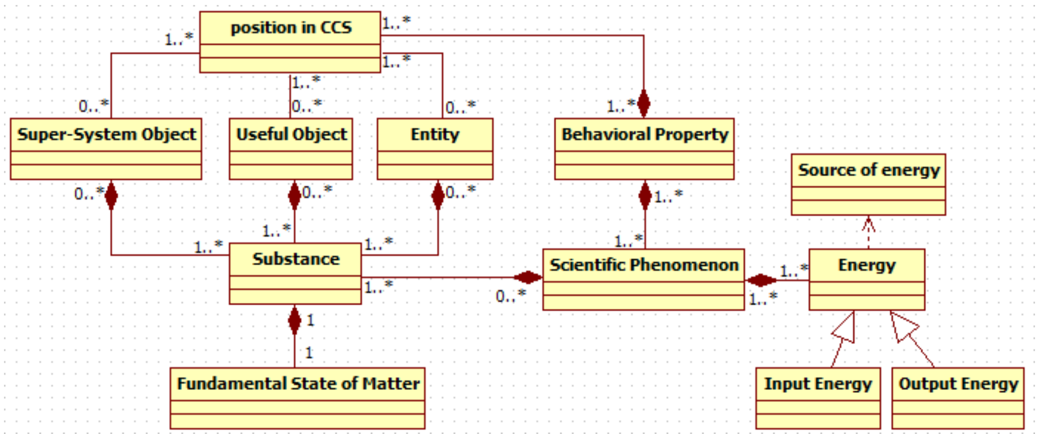

Fig. 8. Behavioral properties in PEEM

2.4. Structural viewpoint

Structural aspect refers to the physical characteristics of system components. Thus the structural viewpoint of a system is characterized as [Fig. 9]:

- Component: represents the structure of subsystems of a system. Each components can be broken down to one or several entities. E.g. the stainless steel shell with the plastic seating area makes the main body of the tumbler cup.
- Entity: represents the smallest structure of components. An entity is a mono-block piece that cannot be dissected as two or several pieces. Each entity exhibits its own associate behavior during system operations. E.g. the plastic seating piece of the tumbler cup.
- Piece part: represents a specific area of an entity that is used to accomplish a system operation. E.g. the bottom surface of the plastic seating piece.
- Assembly: represents the assemblage manner of system entities physically during and out of system operation. E.g. the manner of assembling the stainless steel shell to the plastic seating area via adhesive silicone.
- Connection: represents the conductivity of energy between the pieces parts of entities in a system. E.g. connection of the gravity force from the bottom surface of the steel shell to the upper surface of the plastic seating piece via pressing.
- Server: represents those piece parts in a connection that serve energy.
- Client: represents those piece parts in a connection that receive energy.

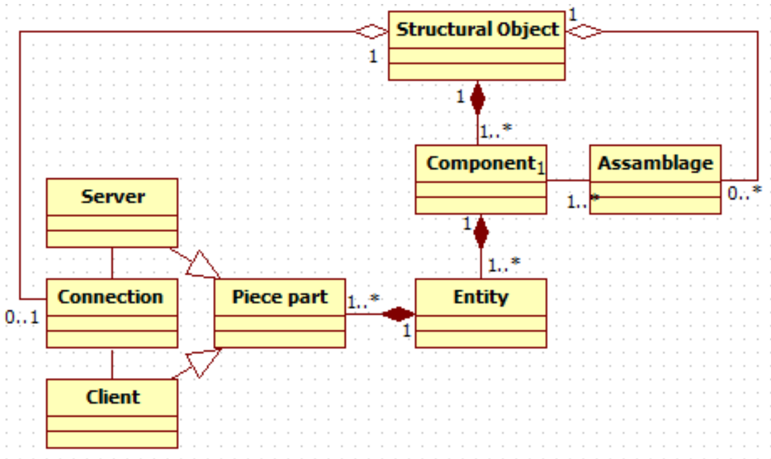

Fig. 9. Structural objects in PEEM

There are several properties for the structural objects that depend on the physical characteristics of entities.

Here some common structural properties are noted. These properties according to the structural entity can be changed or enlarged [Fig. 10]:

- Geometry: represents the shapes in space mathematically.
- Density: represent the volumetric mass of an entity.
- Material: represents the common name of the chemical substance.
- Color: represents the spectrum of light perceived in the look of each entity.
- Weight: represents the force on an entity due to gravity.

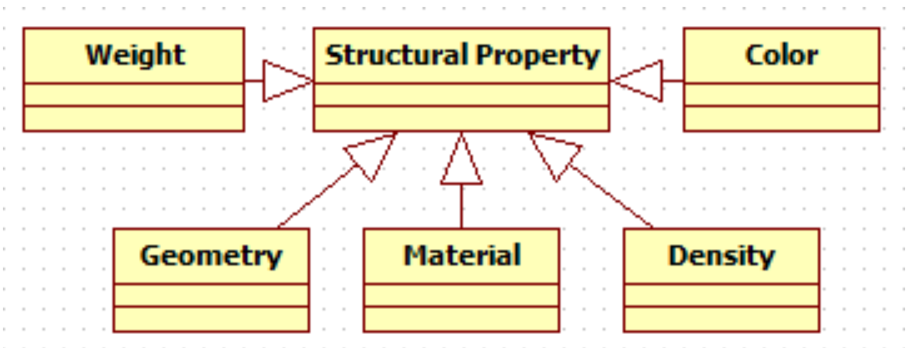

Fig. 10. Structural properties in PEEM

3. An object diagram example in PEEM:

This section prepares an object diagram for the tumbler cup [Fig. 1] in PEEM to illustrate the implementation of the product model and clarify the terms used in this product model. Figure 11. presents the five function types in the tumbler cup with the function properties.

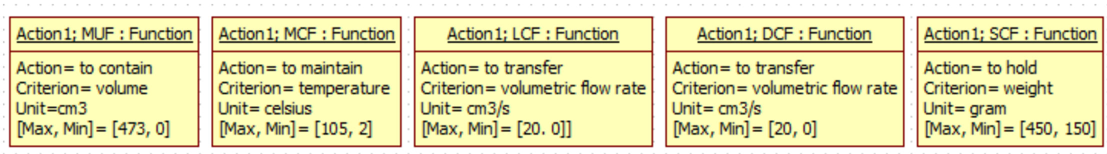

Fig. 11. Defined function objects in the tumbler cup.

Figure 12. shows the super-system objects, the main specific consumers, the main specific operators, and the main useful object of the tumbler cup.

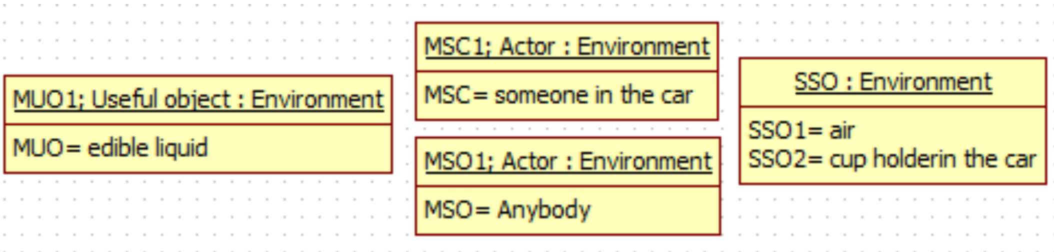

Fig. 12. Useful object, Actors, and Super-system object of the tumbler cup.

Each function is supported with a chain of structure and its behavior. Tumbler cup structure consists of five entities [Fig. 13.].

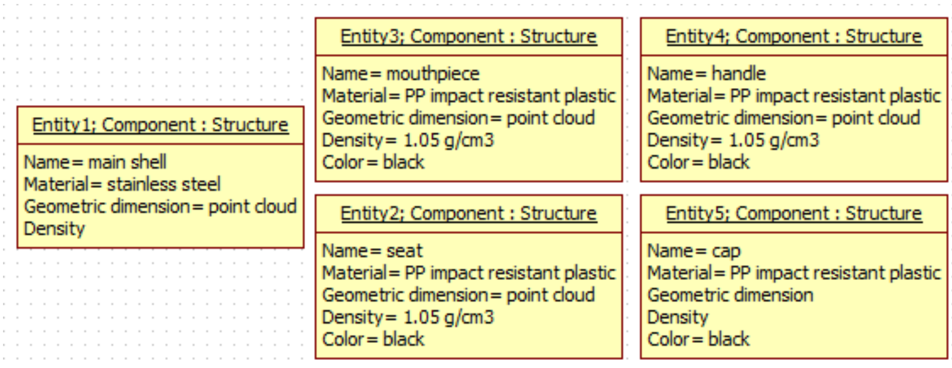

Fig. 13. Structural entities of the tumblercup.

Figure 14. shows the behavior of the related structure to support the MUF of the tumbler cup.

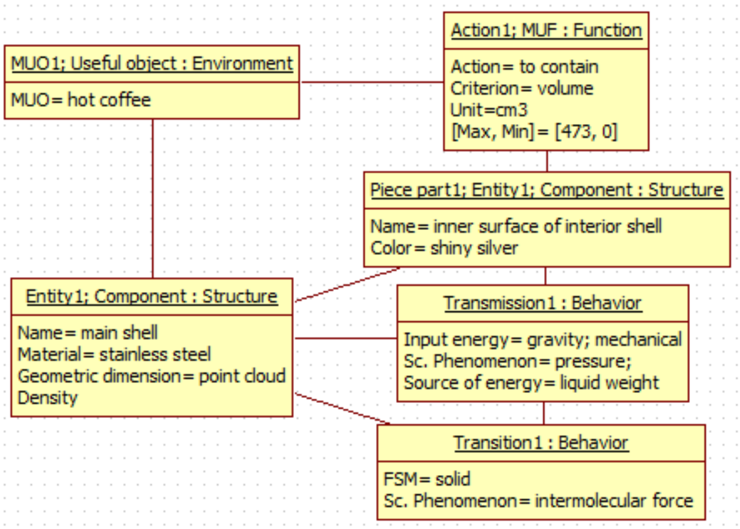

Fig. 14. Mechanism of supporting the MUF of the tumbler cup.

Figure 15. shows the mechanism of supporting the MCF of the tumbler cup.

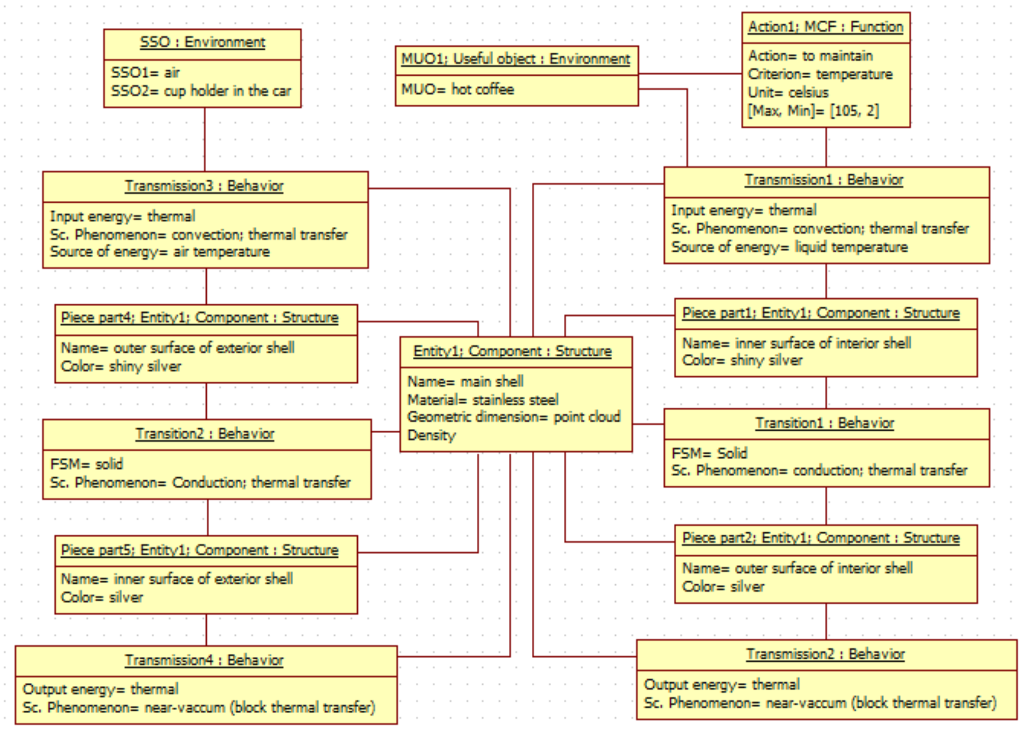

Fig. 15. Mechanism of supporting the MCF of the tumbler cup.

4. Conclusion

The product evolution exploring model (PEEM) is a new product model with the aim of capturing the information of technological systems. This information include the technical characteristics of systems as the applied knowledge on them during design activities. The objective is to make a proper data base for supporting the framework of inventive design performance measurement system (IDPMS). IDPMS is a framework for measuring the performance of design activities that uses PEEM as a data-capturing interface along its operation. PEEM helps to explore the changes in technological systems by studying their technical characteristics. The mechanism analysis in PEEM is based on TRIZ as the main feature of this product model against the other product models. PEEM can be integrated in STEP AP 203 (or some other AP) or uses the complementary models as the open assembly model (OAM).

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